Maintenance

The *Picturephone*® System:

Maintenance Plan

By H. J. DOUGHERTY, E. B. PETERSON and M. G. SCHACHTMAN

(Manuscript received September 23, 1970)

The addition of Picturephone® *service to the communications services offered by telephone operating companies requires that additional maintenance tasks be performed by the plant forces. The* Picturephone *plan provides the structure for integrating the new video telephone maintenance functions with existing telephone maintenance functions. Maximum use of built-in testing features in the switching machine and the inclusion of transmission testing facilities that are a logical extension of telephone testing arrangements provide economical and comprehensive tools for accomplishing the complex tasks of installation, circuit acceptance and trouble isolation. The flexibility of the plan permits the assimilation of advanced techniques into the field as well as prompt appraisal of field experience.*

The plan is described in terms of its major segments, i.e., maintenance for switching, lines and trunks. The interaction of the maintenance hardware arrangements with the Picturephone *plant is outlined together with an overview of the work locations and examples of tasks to be accomplished.*

I. INTRODUCTION

Maintenance planning for *Picturephone* service has proceeded concurrently with the overall planning of equipment and service arrangements. Subscribers will expect *Picturephone* service to be of high quality and to provide nearly trouble-free operating performance. As seen in the other papers in this issue, the complex electronics used to provide *Picturephone* service has the potential to complicate the traditional maintenance functions of trouble detection, isolation, and repair. As in other aspects of the basic concept of *Picturephone* service, the maintenance will be integrated with the current maintenance and administrative operations of the telephone company, providing distinct cost advantages.

Maintenance and Plant Operations in the telephone operating company can be classified into three broad headings:

(*i*) Preparing for service.
(*ii*) Providing service.
(*iii*) Sustaining service.

The first of these categories involves selection of cable pairs and verification that telephone plant is suitable to provide service ordered by a customer on an appropriate service date. Normally, a suitable pool of unassigned equipment is available to provide the service so that the need for holding a service order can be avoided. Next, the implementation of the service order requires that the selected equipment be connected and thereby dedicated to the use of a single customer in the case of individual lines or the aggregate of customers in the case of trunks and central office equipment. Verification that these equipments and interconnections are in fact operable is required before the service may be started. Finally, there will be occasions after the start of service when trouble arises, requiring maintenance action.

Planning for maintenance has also recognized that *Picturephone* service is a new and complex service that initially will be provided on a limited basis. When considering maintenance, the complexity and limited scope of initial *Picturephone* service work at cross purposes. Complexity (and newness) coupled with inexperienced craft people suggest the need for intricate and expensive test equipment designed to make decisions for the craft people (GO-NO-GO testing). A limited initial network, however, can ill afford high-priced hardware since the per-customer costs become excessive. The tradeoff between these factors was decided by the projected growth rate during the initial years. In the absence of a clear indication that a strong growth of service would occur in the initial period, a large expenditure for complex maintenance hardware is not justified. An acceptable alternative is the use of less expensive hardware, operated on a manual basis, coupled with careful training of craft people capable of adapting to a variety of situations. The shortage of skilled manpower complicates this approach, but it is anticipated that the measured growth of the service will not overwhelm existing training capability. During the initial service period, additional information will be gathered to guide the design of the next generation of complex and automatic hardware capable of quality maintenance for a system of increased size and utilizing generally available craftsmen.

II. MAINTENANCE AND OPERATIONS PLAN

2.1 *Basic Considerations*

The pbilosophy that has guided the planning of *Picturephone* maintenance operations has been based upon a series of objectives, including:

(*i*) Arrangements to insure service integrity and charge accuracy.
(*ii*) Features for automatically detecting and identifying troubles.
(*iii*) Features for manual trouble verification, location, and repair with centralized testing facilities where feasible.
(*iv*) Provision for one-man test operations to tbe maximum extent possible.
(*v*) Capability of adding additional automatic test arrangements as service demands increase.

Primary emphasis was placed on means required to insure that calls originated by customers are completed to the destinations desired with accurate recording of charges. One audio and two video transmission paths must be established between the originating customer and tbe distant party. Failure to complete any of these paths should always be detectable so as to avoid false charging and to promptly indicate a need to redial. Where possible, trouble detection should result in an alarm or trouble record and removal of faulty equipment from service. Receipt of the trouble indication should cause immediate action by the maintenance forces. Early corrective action is enhanced if one-man test operations are provided. Automation of maintenance functions promises to provide further cost reductions as the scope of *Picturephone* service is expanded. As mentioned in the introduction, close coordination with telephone maintenance was a necessary consideration in realizing all of these objectives. Work toward meeting these objectives has resulted in a System Maintenance Plan, the subject of this article. To grasp the scope of the plan, one must recognize that the designers of component facilities and subsystems specify for their individual subsystems the specialized techniques and tools required for maintenance. In general, these items (installation test sets, trouble detection circuits and alarms and special test sets for trouble isolation and repair) are tailored to the specific hardware item and do not result in system interactions. The System Maintenance Plan deals with the ensemble of subsystems that combine to make up the *Picturephone* service network.

This plan anticipates a *Picturephone* system that is not static, but

is constantly growing and changing. New station arrangements, new subscriber lines, and new trunks between switching offices must undergo *overall installation and acceptance testing*. Additions and rearrangements can adversely affect adjacent equipment through human error and therefore *routine performance testing* is required to detect degrading service situations due to the foregoing as well as normal aging effects. Failures detected by routine tests and failures reported by trouble alarms require that *trouble isolation testing* be instituted on some major portion of the overall system. These three types of testing on the overall system employ similar principles and require much the same craftsman training. In addition, consolidation of training programs and common use of test sets for the three types of testing result in cost savings.

Practical considerations of administration dictated that hardware development and the procedures for the three types of testing continue to be oriented toward the separate areas of responsibility as follows: (*i*) central office switching, (*ii*) line and station, and (*iii*) trunk maintenance. The plan envisions that administrative procedures and the organization of training programs, Bell System Practices, and records be divided according to these three responsibilities.

2.2 *Work Locations*

Figure 1 is a simplified block diagram of a *Picturephone* switching office, the local area served, and the trunking connecting the office with the remainder of the *Picturephone* network. The figure shows the work locations for switching, line and trunk maintenance.

Maintenance operations associated with the switching machine are largely automatic and take advantage of the common control and maintenance features provided for telephone maintenance. Telephone switching machines provide for per-call tests to verify the operation and continuity through the switch. In addition, as an aid for operational and transmission testing, automatic test terminations are normally available to enable craftsmen at distant telephone offices or on customers' premises to check circuits without the need for manual assistance at the switching machine location. Similar automatic test equipments are planned for the wideband switching network when *Picturephone* switching capability is added as shown in Fig. 1.

The manual work location for switching machine maintenance is at the No. 5 crossbar master test frame in the maintenance center. Trouble detected by the automatic equipment is indicated to the

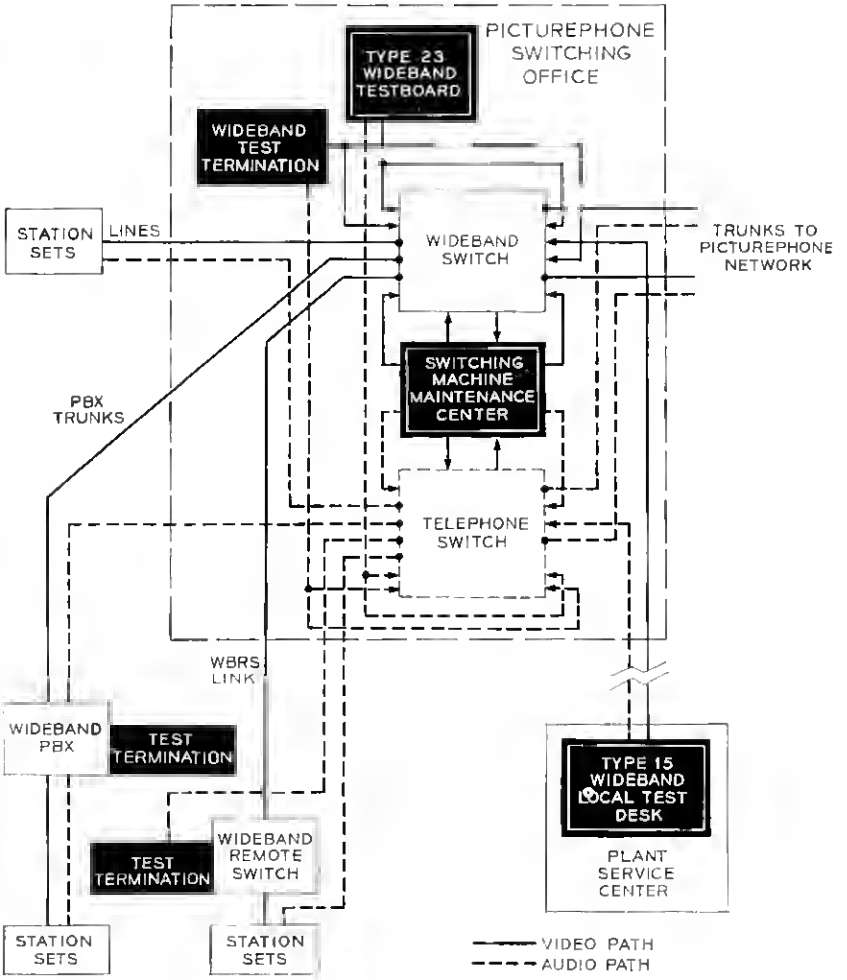

Fig. 1—*Picturephone* local office configuration with maintenance equipment and work locations (simplified).

craft people located there, and verification tests are conducted using the test access provided at the test frame. Full manual control of the machine (both telephone and wideband portions) is exercised from this work location.

The basic plan for *Picturephone* service provides that, in most cases, the customer's video service will be logically related to his telephone service by the regular telephone number. Telephone line maintenance

is centralized in a plant service center; *Picturephone* line maintenance can be accomplished from the same location. Thereby, the line record cards for both services are coordinated and uniform administrative procedures can be used to handle all customer troubles. Telephone line testing is accomplished from a telephone local test desk[1] and *Picturephone* line testing is accomplished from a wideband local test desk of new design. For both telephone and video, test access from the centralized test location to the thousands of lines served by the office is via the switching machine. Experience has shown that this means of access for telephone testing is quite adequate; for video, the minor variations in measurements due to variable paths through the switch must be considered, although switch performance is a minor source of impairments.[2] Figure 1 shows the work location for video testing and the test access path.

The recent trend in the routine testing of telephone trunks is toward centralized control of the automatic testing, particularly where there are a large number of trunks and trunk groups. In the initial years, the number of *Picturephone* trunks will be small and, in general, not integrated with the telephone network. *Picturephone* interoffice trunks form an independent network of six-wire trunk facilities[2,3] dedicated to *Picturephone* service use. Similarly it is not expected that the *Picturephone* hierarchy of switching offices will coincide with the telephone hierarchy. In light of the relatively small numbers of trunks and offices, it is clear that a complex arrangement for centralized maintenance cannot be justified at this time. In addition, the restrictive performance objectives for trunks[2] require precise measurements, a sufficient technical challenge in itself, and centralization adds the potential of additional measurement error. In contrast to lines, the independence of *Picturephone* trunks from telephone trunks means that there are no overriding administrative or record considerations that make it imperative to test telephone and *Picturephone* trunks from the same location. The work location is at a testboard in the vicinity of the wideband *Picturephone* switch (see Fig. 1). This nearby location is governed by the need to maintain nearly flawless transmission performance in the test access path to accomplish the precise measurements needed for trunk maintenance. Short access trunks, using initial service transmission equipment, achieve the required "transparency" at reasonable cost. Centralization, however, must be anticipated, but it remains for future consideration. To this end, switched access was chosen for all wideband test access (in contrast to some telephone practices where access is on a per-circuit jack basis) because of the potential for future centralization and the technical complications of

providing dedicated per-trunk jack type access for the wideband circuits at standard levels (without introducing intolerable path-length variations).

2.3 *Additional Considerations*

In addition to factors such as maintenance responsibilities and tbe associated work locations and test access, provision of transmission testing equipment for line and trunk testing has been based on the following additional considerations:

(*i*) Initial service analog transmission facilities for lines and trunks are essentially similar.
(*ii*) The nature of troubles and tbeir prevalence will not be well defined until service experience is obtained.
(*iii*) Training of craftsmen will be facilitated if testing equipment and procedures are analogous to those of existing telephone and carrier systems.
(*iv*) Improvement and updating of individual equipment will be facilitated if, initially, test sets are restricted to single categories of tests and are *not* consolidated and if interactions between test instruments are kept minimal.
(*v*) Costs and development intervals would be minimized if "on-tbe-shelf" commercial test sets could be utilized or modified for *Picturephone* service.

The system maintenance plan resulted from a synthesis of all of the aforementioned considerations of organization, technology, and cost. The following sections deal in greater detail witb the plan from tbe standpoint of the switching machine, lines, and trunks.

III. MAINTENANCE OF CENTRAL OFFICE AND SWITCHING EQUIPMENT

3.1 *Maintenance and Plant Operation Functions*

The use of a wideband switching network similar to the audio network and the inclusion of *Picturephone* features in existing common control circuits permit the *Picturephone* maintenance and plant operation functions to be combined with the present audio functions. Figure 2 illustrates the major blocks of the *Picturephone* system and the maintenance facilities for recording trouble information and testing troubles in a No. 5 crossbar central office.*

* Initially *Picturephone* service is supplied only from No. 5 crossbar systems equipped with a wideband switching network. The maintenance plan, however, is designed to anticipate provision of *Picturephone* service with other switching machines when suitable wideband networks are developed.

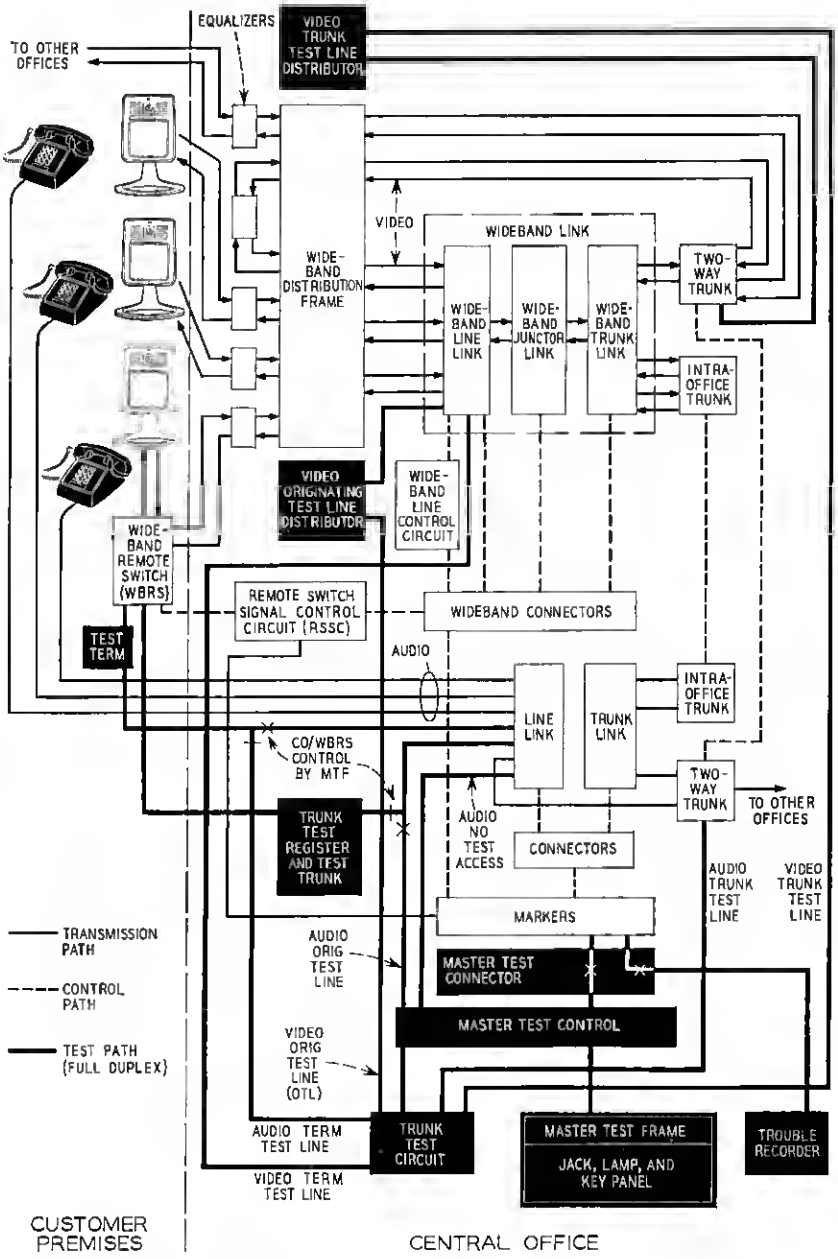

Fig. 2—No. 5 crossbar central office maintenance arrangements with *Picturephone* service.

3.1.1 *Trouble Detection*

Provision is made to automatically verify the operation of common control circuits and the integrity of the transmission path. Rather than develop a number of special test arrangements that would continually check the video features, troubles are detected on a per-call basis, thereby avoiding false charging when troubles are encountered. The per-call detection tests performed on the video equipment are (*i*) tests of common control circuits, (*ii*) checks of the control signals associated with the remote switch, (*iii*) double connection tests, (*iv*) false-cross-and-ground tests, and (*v*) continuity tests.

3.1.2 *Verification of Common Control Circuits*

Verification of the operation of common control circuits handling the video call is performed in the same manner as for telephone since most of these circuits also process audio calls (e.g., marker, connectors, etc.). The generators providing the video supervisory signals (VSS),[3] the continuity oscillator and detector circuits, and the control leads connecting to the wideband remote switch units are verified on a continuous or per-call basis to insure that signals are transmitted within specific limits. A continuous monitoring of the video supervisory signal level is made at −4.5 dB with reference to the 0 PTLP.* A comparison of the continuity peak signal voltage level with a high and low reference voltage is made on a per-call basis.

The coding of the dc signals transmitted via the remote switch signal control circuit (RSSC) are also checked at both the RSSC and wideband remote switch (WBRS) on a per-call basis so that any trouble detected will permit a second attempt to be made to select a path through the remote switch. Replication of common control circuits is provided to permit second attempts to be made using alternate circuits. If second attempts fail, the common control circuits route the call to reorder or announcement thereby protecting accuracy in charging.

3.1.3 *Integrity of the Path*

Upon recognizing a request for *Picturephone* service, the common control circuits select idle audio and video paths and verify that they are capable of being used to connect the originating location with the

* Zero *Picturephone* Transmission Level Point, a reference point specifying signal levels that is analogous to specifying elevation relative to sea level. At this reference point, the *Picturephone* signal is the same level as the output of the station set (100-ohm impedance).

terminating location. Double connection and false-cross-and-ground tests similar to those made in the audio path are made on the video path. In the event of a failure of these tests, the common control circuit makes a second attempt to select another path through the switching network. If no failure occurs in the above test, a continuity test of both the originating and terminating video path is performed by inserting a 12-kHz sine wave at a nominal level of −20 dBm* through the network. This test signal was selected based on economic considerations of the generator and detector arrangements, holding time to make the tests, and probability of faults affecting the megahertz bandwidth of the *Picturephone* signal. In making a continuity test, the 12-kHz test tone is sent over the transmit pair and returned over the receive pair. It is looped around at the station set via a zero loss loopback if customer loop facilities are being tested or at the distant office wideband trunk circuit via a 3-dB pad if trunk facilities are tested. The returned test tone is checked for ±1 percent frequency and ±4.1-dB level on loops and ±1.3-dB level on analog trunks.

3.1.4 *Trouble Reporting*

When trouble is detected during call processing, the switching equipment determines the degree of severity of the trouble and activates a minor or major alarm.† This is an audio and visual alarm indication and is accompanied by a trouble record card in the No. 5 crossbar system. The circuits associated with the call at the time the trouble is detected are identified in order to facilitate locating the cause of the trouble. In the event that trouble is detected when common control circuits are not attached to the malfunctioning circuit, such as improper MF outpulsing to a distant office, lamp indications are activated at either the maintenance center and/or equipment to identify which circuit is in trouble.

3.1.5 *Trouble Location*

Provision is made to test the wideband functions from both the switching maintenance center and the equipment location. After a trouble is detected and reported, a central office craftsman analyzes

* Measured at 0 PTLP.

† Occurrence of major or minor alarms is generally determined by the potential for disrupting many (major) or a few (minor) customers. For example, marker failure is a major failure while a signaling circuit failure will generally be considered minor.

the report and initiates appropriate tests to determine if it still persists. The majority of troubles occurring in the central office are expected to be identified by a single test. Arrangements have been made at the maintenance center to select any video path through the network, any wideband trunk circuit, either of two VSS generators and any WBRS. Additional control functions include the capability to cancel continuity checks, make a circuit busy to service and force trouble records on a test call.

3.1.6 *Administration and Operation*

Standard Bell System Practices have been prepared describing the central office maintenance arrangements required for *Picturephone* service. These will be incorporated into the existing Controlled Maintenance Plan (CMP) and Plant Management Instructions that are used to administer the switching system. The CMP prescribes scheduled routines for preventive maintenance in the office as well as methods for evaluating the equipment performance level of the office. Plant registers are provided to record the peg count of the total number of *Picturephone* calls requested and a total of those calls that fail. The present plant work unit plans that are used in determining the productivity of craftsman will be modified to include the added *Picturephone* functions described above.

Table I is a summary of the central office maintenance functions associated with *Picturephone* service.

3.2 *Work and Test Access Locations*

As noted in Section 3.1.5, the primary test facility in the central office will be the switching maintenance center. In the No. 5 crossbar system this is the master test frame which has a trouble recording facility adjacent to the control equipment. Test access to any central office circuit is gained by providing the marker with priming information from the master test control circuit. Originating test lines and terminating test trunks are connected to the maintenance center for testing the network, WBRS, and trunk circuits. Test access is available at the maintenance center for use with a *Picturephone* set in order to evaluate the qualitative performance of the transmission over the switching circuits tested. This same access is also used for measuring the central office transmission characteristics described in the paper on the transmission plan.[2] Provision was made in the continuity test circuits and VSS circuits to perform marginal tests of the frequency and level of their signals.

TABLE I—MAINTENANCE FUNCTIONS FOR *Picturephone* SERVICE IN CENTRAL OFFICES

AUTOMATIC TROUBLE DETECTION AND RECORDING	
Common Control Circuits	Consistent with present test on a per-call basis.
Continuity Test	All transmission paths checked on a per-call basis.
Double Connection Test	Foreign potential and grounds within the switching network on a per-call basis.
Video Supervisory Signal Supply	Continuous trouble detection and automatic transfer to duplicate supply circuit.
Wideband Remote Switch Control	Per-call trouble detection and automatic transfer to duplicate control circuit.
Alarms and Recordings	Visual and audible alarms at central point. Trouble record card with call details.
AUTOMATIC ACTION AFTER TROUBLE DETECTION	
Call Set-Up Trouble	Second trial using alternate equipment or path through switching network. Reorder after second trial failure.
MANUAL TROUBLE LOCATION	
Equipment Faults	Means for testing common control circuits (markers, connectors, etc.). Means for testing detection circuits (continuity, double connection test, etc.). Means for testing wideband remote switch control leads.
Path Faults	Selection of any path through switch. Selection of any trunk or WBRS link even if "maintenance busy."

3.3 *Testing Arrangement and Procedures*

The craftsman initiates tests of the central office wideband facilities either on a routine schedule or on a trouble report basis. Using the information he has received (for example a trouble record), he identifies the type of call on which the report was received and the circuits involved in handling tbe call. Using the controls at the maintenance center, he selects the same circuits and establishes a test call in order to verify the circuit operation. If the test call fails, he uses schematic drawing information, such as the sequence charts, to locate the specific cause of the trouble.

Several significant factors associated with *Picturephone* central office maintenance procedures are: (*i*) the compatibility with existing procedures (most of the test operations are identical to present testing of audio circuits), (*ii*) the ability to perform tbe tests without assistance of additional craftsmen (one man testing), and (*iii*) the verification and location of the defective unit, in many cases, from the maintenance center. This latter factor minimizes the need for a craftsman to be at the equipment for other than actual repair.

IV. MAINTENANCE OF LINES

4.1 *Maintenance and Plant Operation Functions*

Line testing is required as part of overall installation and acceptance testing (service order procedures), for routine testing, and to isolate troubles referred to the plant service center. All *Picturephone* lines (both individual and key service) can be accessed for testing. Included are remote exchange lines, lines served from wideband remote switch units and PBX lines. Measurements are on a loop basis with signals transmitted through loopback circuits provided in the station set or the Key Telephone System (KTS) equipment. These loopbacks operate to connect the two directions of transmission at equivalent levels so as to permit full wideband round-trip testing.

Measurements are made of echo rating,* broadband noise, crosstalk, low frequency noise, single frequency interference, impulse noise, and flat gain variation.[4] All of these impairments are allocated as discussed in the article on the transmission plan.[2] In addition, means are provided to interrogate the cable equalizers[5] to locate gross faults in

* At the present time, a measurement algorithm suitable for field measurements of echo rating has not been developed; gain-frequency response measurements are being substituted for direct echo rating measurement as a first approximation.

equalizers or in connecting cable. Audio measurement capahility is associated witb the video-measuring facilities. Normal techniques presently applied at local test desks (LTD) such as the No. 14 type are used. Any confirmed audio-only troubles, however, requiring extensive measurements can be referred to the telephone (only) LTD so as not to tie up expensive video testing facilities.

No requirements for automation of routine testing (otber tban the per-call tests mentioned in Section III) were specified for the initial service arrangements. Independent means for measuring each of the impairments considered in the performance objectives[2] is the only practical course until experience with the system can be obtained. However, access arrangements and test terminations have been defined to aid in trouble isolation. Provision is therefore made for switching machine access to any desired line with the ability to manually cancel continuity check and to control ringing. Selection of test access to different office locations is by key control. Connection of test instruments is also by key control, eliminating both the need for cords and possible operator error.

4.2 *Work and Test Access Locations*

The major test facility for line maintenance is the No. 15 *Picturephone* local test desk shown in Fig. 1 and described more fully in a companion paper.[6] This desk is arranged to normally obtain switched access to lines via a test trunk having an appearance on the trunk link side of the *Picturephone* switching network (No. 5 crossbar). This trunk is designed to be as nearly transparent to *Picturephone* signals as possible and includes a means for checking the transmission integrity of the access path hefore testing. The test desk also has auxiliary access to lines via the main distributing frame (MDF) which is the interface between the office equipment and the outside plant. This MDF trunk must be patched manually to line appearances permitting measurement of the outside facilities alone or (in conjunction with the switched access trunk) the central office equipment alone.

In addition to the test trunk providing test access from the No. 15 LTD, there are two other test trunks in the central office for line maintenance. One provides access to the video switcb at the trunk link frame from the master test frame. This trunk permits testing of lines in small offices not equipped with a No. 15 LTD. The second trunk is a test termination functioning as a station ringer and video test facility. Sucb terminations are used by station installers and repairmen to verify the proper operation of station sets.

To permit sectionalization of troubles and to provide a known termination and test access point, test circuits are provided at PBX and WBRS locations. These test terminations have a listed directory number (in the case of the WBRS) or a PBX extension number. Test calls can be directed by the deskman over a selected PBX trunk (or WBRS link) to the appropriate test termination to determine that the trunk (link) is satisfactory. This technique is illustrated in the next section below. Note that while the trunk (link) is used for test access to lines served from the PBX (WBRS), its maintenance is a trunk responsibility (see Section V). The test terminations also provide access for testing should (*i*) a PBX repairman be dispatched to the PBX or (*ii*) a central office switchman desire to test at a WBRS located in a central office not provided with full *Picturephone* switching.

As stated previously, provision of a wideband loopback circuit at customer locations avoids the need for always dispatching a repairman to the station location for trouble isolation, circuit order or routine tests. A limited need to involve the subscriber during trouble isolation is unavoidable. Once the trouble is isolated to the customer location, then a repairman is dispatched to the customer premises where testing as required occurs using portable test equipment: (*i*) on a one-man basis to the station-ringer test termination, or (*ii*) on a two-man basis with the desk man at the No. 15 LTD.

4.3 *Testing Arrangements and Procedures*

Video measurements from the test desk are accomplished using the following test instruments, described in a companion paper[6]

(*i*) Wideband oscillator,
(*ii*) Wideband voltmeter,
(*iii*) Waveform oscilloscope,
(*iv*) Wideband noise measuring set,
(*v*) *Picturephone* station set,
(*vi*) *Picturephone* test signal generator, and
(*vii*) *Picturephone* fault locating test set.*

The adjustable wideband oscillator together with the wideband voltmeter are used to obtain gain-frequency response measurements. Pre-programmed or switch selection of test frequencies, although desirable operationally, are not provided since measurement pro-

* A portable test set normally used by central office repair forces available for connection to test desk and boards as required on a patch cord basis. Other portable test equipment may also be connected as required.

cedures are expected to change as experience is gained. Therefore, the oscillator must be set manually to any desired frequency in the *Picturephone* band. The wideband voltmeter measures on a broadband basis; the expected noise on *Picturephone* circuits will be such that selective measurements are not required to obtain accurate gain-frequency data. The waveform oscilloscope has provisions for examining the video waveform transmitted either from (*i*) the subscriber's station or (*ii*) the test signal generator and/or the *Picturephone* station transmitter in the No. 15 LTD on a round-trip basis via the various loopbacks. This will be a valuable tool for trouble isolation. The oscilloscope has provisions for examining the waveform at line rate (8 kHz) or field rate (60 Hz). The sync pulse can be examined without de-emphasis to determine sync distortion. The video can be examined with de-emphasis to view waveform distortion. The test signal generator produces signals especially useful for these tests.

The wideband noise measuring set is equipped to measure either weighted broadband noise or impulse noise. When used to measure broadband noise, it will measure both random noise and single frequency interference. The requirements are such that a single circuit order or routine measurement will indicate failure due to either source. The measurement is made on a loopback basis by measuring the sum of the near-to-far plus the far-to-near noise. Impulse noise is measured by recording the number of impulses exceeding a variable threshold. Low frequency noise is measured by the wideband voltmeter.

Crosstalk measurements use the test signal generator to transmit a distinctive pattern that is observed on the waveform oscilloscope or *Picturephone* set receiver. In general, only self-crosstalk can be measured; the requirement for self-crosstalk is more severe than worst disturber crosstalk[2,7] due to the assumption that multiple exposures of the same signal source produce a greater interference effect than multiple disturbers where each disturber is from a different signal source.

For initial service, circuit acceptance and routine tests are the same although routine tests have wider limits.* The data from the initial installations will be closely observed to determine whether the limits or routine intervals should be changed.

---

* *Picturephone* service is engineered to provide high-quality service under expected conditions of plant variability. The test limits of routine tests serve to trigger corrective action only when performance is degraded. Allocation of margin principally to plant variability (and not installation error) is accomplished through tighter circuit acceptance limits.

Trouble isolation testing will normally involve a repetition of the routine tests (if the test is due to a trouble report) to obtain verification test data for comparison to the installation and routine records. As the expected troubles are quite varied, a flow diagram approach has been adopted to guide the deskman in sectionalizing the trouble. Figure 3 illustrates this procedure for a station trouble where the

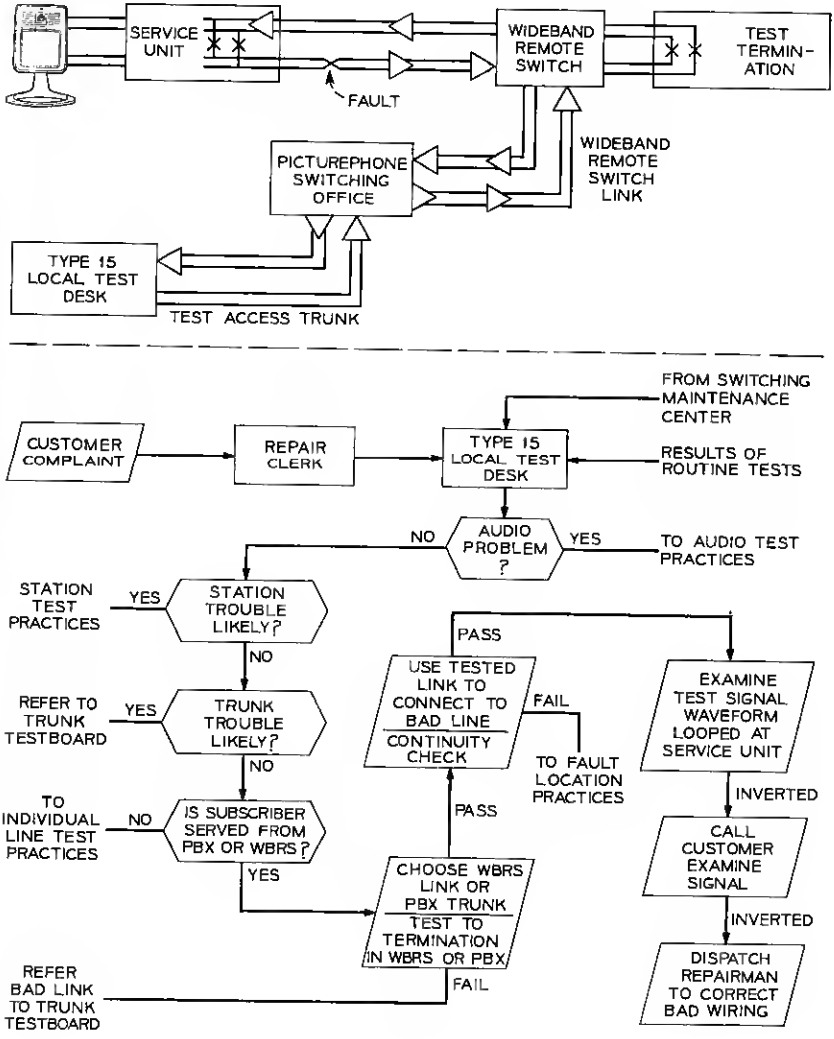

Fig. 3—Example of line fault location.

station is served directly from a WBRS. The trouble example is a reversal of leads in the transmission path from the subscriber to the WBRS, possibly resulting from rearrangements at the customer's premises. The symptom of this trouble is the inability of the called party to see the customer who is in trouble. However, the calling customer can see the called party. Although not shown in the figure, operational practices provide instructions for the tasks indicated in the blocks. The actual procedure flowchart is more detailed and has been simplified for the figure. Note that the flow diagram provides that possible troubles in the access links be referred to the organization having responsibility for trunk testing. The No. 15 LTD has the capability to direct signals over chosen links to the WBRS test termination so as to verify the fitness of the remote switch link used as an access path to the WBRS.

It is expected that detailed transmission measurements can be adequately made from the test desk in most cases. Complex test equipment will not be required in the field. Experience may indicate, however, that testing resolvability is not adequate when the transmission distance between the station and the test desk is great (possible with a long line served from a WBRS that is also a long distance from the *Picturephone* switching office). The maintenance plan provides for access for portable test sets at a jack located in conjunction with the test termination at a PBX or WBRS.

V. MAINTENANCE OF TRUNKS

5.1 *Maintenance and Plant Operation Functions*

In initial service, three types of trunks are provided and the testing procedures differ accordingly:

(*i*) PBX trunks or WBRS links—providing transmission between the wideband line link and a PBX on customers premises or a wideband remote switch in a central office or on customers premises. The PBX trunk is a six-wire trunk with the audio and video path dedicated to *Picturephone* calls only. The WBRS link is a four-wire link transmitting only video; the audio is carried on the customer's regular audio pair.

(*ii*) Interlocal and toll connecting trunks—dedicated six-wire analog trunks connecting class 5 (end) offices or class 5 to class 4 (toll) offices. In general, these will be of moderate length and confined to a local analog area within a city.

(*iii*) Intertoll trunks—dedicated six-wire trunks comprising analog

or combined digital-analog facilities connecting class 4 offices. For initial service, all switching will be analog and therefore all trunks will have analog end sections requiring analog maintenance arrangements.

In telephone service, it is the usual practice to provide fully equipped testboards only at toll offices. Less sophisticated arrangements are normally found at class 5 offices. For *Picturephone* service, testing arrangements are designed to provide testboard functions at all classes of office.*

The same measurements will be required on *Picturephone* trunks as on lines. Measurements however, will be made on both one-way and looped bases as is appropriate to the measurement and type of trunk. The availability of testboard arrangements at both ends of toll connecting and intertoll trunks assists in accomplishing the tighter requirements that are consistent with trunk objectives.[2] Routine measurements will be more frequent, and test termination arrangements are provided to facilitate single-man routine testing wherever possible. Audio testing ability is included with the video because of the separate dedicated network approach associated with *Picturephone* trunking.

For initial service, the facilities providing trunk transmission are configured using the same hardware as line facilities, although to different engineering rules. Hence the same considerations of flexibility in testing approach apply. Initial requirements for test equipment therefore stressed independent means for measuring the expected impairments, using the same instruments provided for line maintenance in the No. 15 LTD.

5.2 *Work and Test Access Locations*

The testboard arrangement designed for initial *Picturephone* trunk testing is the No. 23 testboard (TB) shown in Fig. 1 and described more fully in a companion paper.[6] This testing arrangement operates in conjunction with a single No. 5 crossbar switching machine. Test connections are established (*i*) between a test trunk appearance on the trunk link to PBX trunks or WBRS links that appear on the line link, or (*ii*) between a test trunk tandem appearance on the line link to any trunk on the trunk link. All connections are made on a six-wire basis. Incoming test calls from distant locations are directed to test

* For initial service, the number of trunks may not justify provision of a full testboard; arrangements would then be made to provide the same testing functions at the switching maintenance center.

trunk appearances (*i*) on the line link in class 5 offices (7-digit telephone number) or (*ii*) on either the trunk link (101 test termination) or line link (7-digit telephone number) in class 4 offices. Only *Picturephone* calls will complete to these trunks.

The No. 23 TB is designed to establish test connections to particular trunks or links and to override maintenance busy signals that prevent completion by the switch of connections to defective trunks. Means are provided in association with the testboard to test the control and signaling functions of any trunk. The design of the wideband switching network to minimize path length variation and the effect of switch multiples permits measurements of a high degree of accuracy to be made although access is on a switched basis. In addition, a calibration loopback is provided at the video trunk circuit of the test access trunk permitting the craftsman at the testboard to verify the transmission performance of the test trunk before commencing a test. It is expected that the transmission path between the testboard and the switch will be measured at frequent intervals to insure the testboard's accuracy as a measurement *system*.

In addition to the 101 test trunk appearance on both audio and video switches, other coded test trunks provide the video equivalent of test terminations used for maintenance testing on the DDD network. A code 100 termination is used for combined far-to-near loss and noise measurements. A code 102 termination is provided for far-to-near low frequency loss measurements and to provide a loopback for more general two-way measurements on a loop basis. The test lines are described more fully in a companion article.[6]

5.3 *Testing Arrangements and Procedures*

The No. 23 TB includes the same video test equipment provided in the No. 15 LTD (see Section 4.3). In addition a voice frequency gain and noise measuring system is provided that is equivalent to that used for maintenance operations at conventional telephone trunk testboards.

Major responsibilities to be carried out at the No. 23 TB are circuit acceptance and routine tests on all trunks leaving the office. These tests are similar to the tests performed from the No. 15 LTD, although to tighter tolerances reflecting the trunk objectives.[2] Tests on PBX trunks or WBRS links are on a loopback basis to the test termination loopback in the PBX or WBRS. Circuit order tests on trunks are in general conducted on a two-person basis between No. 23 TBs at the ends of each trunk. Routine tests are on a loopback basis to distant

102 test terminations. These routine tests are required more frequently during the period of initial service since temperature regulation is not provided for trunks. Routine tests serve to monitor trunk performance and serve as an indicator of the need for trunk realignment.*

Trouble isolation is basically a sectionalization procedure utilizing test terminations and the switched access from the No. 23 TB. Figure 4 provides an illustration of this technique. Office A is the control office responsible for maintenance of the trunk. An open circuit at a widehand distributing frame as indicated has resulted in failure of continuity check on a call from A to B. The trouhle indication at A is reported to the No. 23 TB at A. The tester at the testboard deduces that the trouhle does not involve the tandem equalizers (1) and (2) since those equalizers are not involved in calls from A to B. He then dials the code 102 test termination at B, receives a signal from office B over the far-to-near path, but no return of a round-trip signal when the test line switches to the loop-back mode. The conclusion is that the trouble is in the near-to-far path. The 102 termination is disconnected and the craftsman redials the code 100 test termination at B. This prevents seizure of the trunk from office B and provides a termination of the trunk during fault location. The craft person then interrogates equalizer pairs (3) and (4), (5) and (6), and (7) and (8), normally tested from office A to obtain a response from the fault locating circuitry. These test all right.

The tester then reasons that equalizer pairs (9) and (10) and (11) and (12) should he tested and, because these can be tested only from office B, a test call is directed to the distant No. 23 TB (via a code 101 test termination). The tester at the No. 23 TB at office B checks equalizer pairs (11) and (12), and (9) and (10). Tandem equalizer pair (13) and (14) is not checked since the continuity failure was between the trunk circuits of offices A and B. Equalizer pairs (11) and (12) and (9) and (10) do not provide a return of the fault locating signal indicating a failed equalizer, trunk circuit or interbay wiring. The tester at office B must therefore check his office. Since the tester at office A is no longer required, he releases the connection and the tester at office B establishes a connection to the code 100 termination at office A, providing a resistive termination for both directions of video transmision. He directs that a patch be

* 12-kHz continuity tests performed on a per-call basis (see Section III) serve to detect gross failure or trunks considerably out-of-limits. They cannot serve as a measurement of misalignment due to temperature.

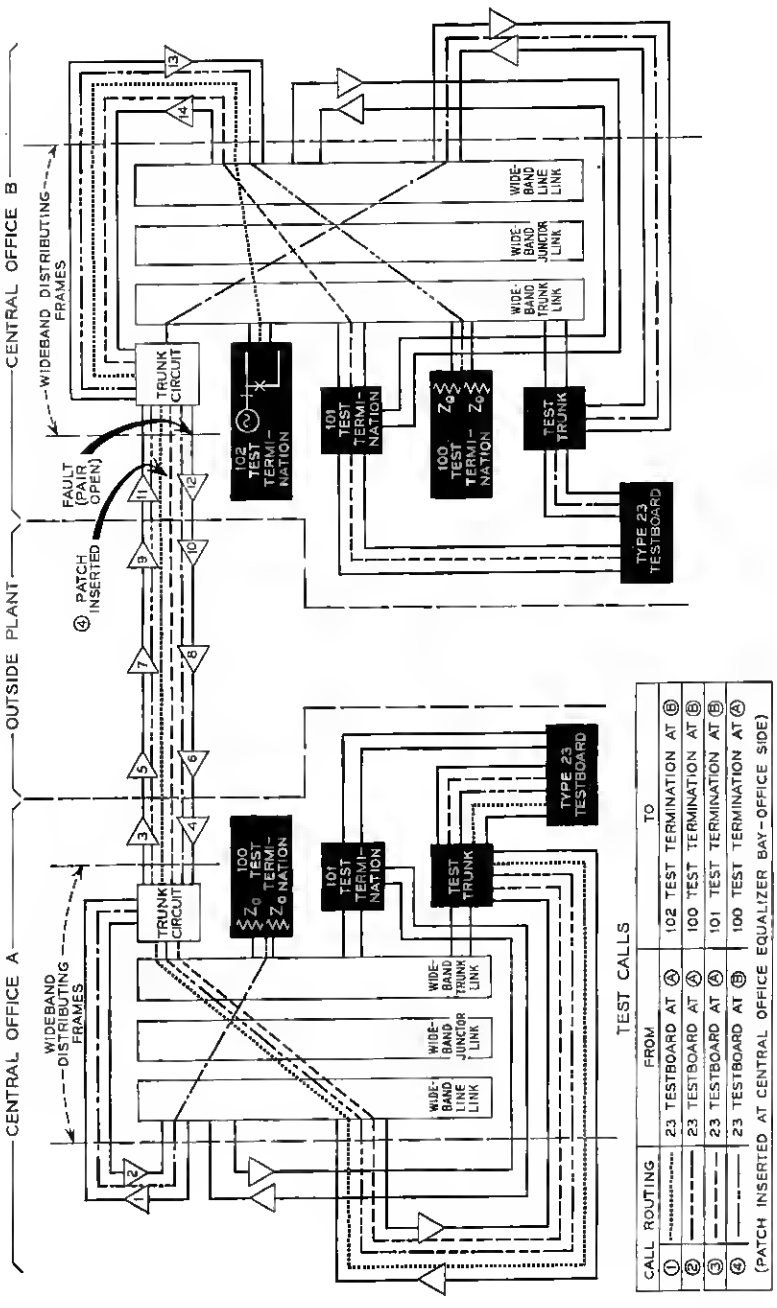

Fig. 4—Trouble isolation on trunks.

inserted at jacks located on the office side of equalizer pair (11) and (12). When he receives no response, he then reasons that the fault is in the cabling or the trunk circuit at office B and refers the trouble to the central office repair forces. They use the test access and control described in Section III to isolate the trouble.

Long *Picturephone* service trunks between central offices consist of both analog and digital portions during initial service. The digital portions utilize facilities that incorporate sophisticated means for determining when transmission is not acceptable. The output of this trouble detection arrangement is coupled to alarm reporting systems insuring that faulty trunks are turned-down from service. The No. 23 TB will be used for overall maintenance of these trunks. However, the nonlinear nature of the codec (coder-decoder) that processes the analog video signals for transmission in digital form prevents meaningful quantitative overall measurements from being made on digital trunks. Quantitative measurements are made on the analog end sections through manually operated loopbacks at the analog-digital interface. Overall qualitative measurements are made using visual appraisal of the *Picturephone* test signal generator signal or any suitable *Picturephone* signal transmitted from the distant end.

VI. CONCLUSIONS

The maintenance plan and hardware developed to accomplish it are expected to result in performance consistent with the premium price of the service. Automatic checks of all components of the video connection at call setup will insure that major failures are promptly detected. Routine measurement of transmission parameters will trigger maintenance action when transmission is out-of-limits. The plan meshes well with existing telephone company organization and procedures and retains flexibility to adapt to unknowns. The associated hardware is within the state-of-the-art and utilizes proven testing approaches.

To improve efficiency and reduce cost, the initial service maintenance performance will be closely monitored. Data will be needed on the man-machine interface and actual performance so that unneeded flexibility now included can be pared and training simplified.

Effort continues to be directed toward planning of improved call-setup testing techniques and off-hours automatic circuit testing to improve the effectiveness of routine testing without heavy manpower requirements.

VII. ACKNOWLEDGMENT

The authors wish to thank their many colleagues at Bell Telephone Laboratories who have been involved in maintenance planning. In particular, the contributions of E. R. Gallun and C. W. Haas, Jr., have greatly influenced the development of the plan. Suggestions, contributions, and criticism by D. N. Carson have been invaluable in establishing testing methods and instrumentalities.

REFERENCES

1. Ritchie, D., Jr., "Improvements in Subscriber Line Testing," Bell Laboratories Record, *30*, No. 8 (August 1952), pp. 337–340.
2. Brown, H. E., "The *Picturephone*® System: Transmission Plan," B.S.T.J., this issue, pp. 351–394.
3. Urich, J. F., "The *Picturephone*® System: Switching Plan," B.S.T.J., this issue, pp. 521–531.
4. Crater, T. V., "The *Picturephone*® System: Service Standards," B.S.T.J., this issue, pp. 235–269.
5. Brown, J. M., "The *Picturephone*® System: Baseband Video Transmission on Loops and Short-Haul Trunks," B.S.T.J., this issue, pp. 395–425.
6. Favin, D. L. and Gilmore, J. F., "The *Picturephone*® System: Line and Trunk Maintenance Arrangements," B.S.T.J., this issue, pp. 645–665.
7. Bunin, B. J., Hirsch, R. B., and Olsen, R. E., "The *Picturephone*® System: Crosstalk Considerations in the Transmission of Analog Signals on Paired Cable," B.S.T.J., this issue, pp. 427–457.